Warning Concerning Copyright Restrictions

The Copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyright material. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction not be "used for any purposes other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

CHAPTER THREE

METHODS AND PRINCIPLES

Memory is an intimate part of who we are. However, despite the fact that it permeates all mental processes (or perhaps because of this), we have little conscious awareness of it. Intuitively, memory seems very ethereal. As described in Chapter 1, for most of history, memory was thought to be beyond objective study. It wasn't until the late nineteenth century that it became sensible to think about systematically studying memory. Because it is so hard, if not impossible, to get a direct look at memory, we need good indirect methods. These often involve an experimenter manipulating what is to be remembered, recording an act of remembering, and then making inferences about memory based on what is observed. In this chapter we first address what an experiment is and how it compares to other types of data collection. Then we examine various methods of memory research. We first look at learning, followed by some tasks that can be used to test memory contents and structure. Finally, we consider issues of conscious introspections. Along with each method we also look at some basic principles of memory whose discovery can be attributed, at least in part, to the methods being presented. For those interested students, ways of calculating some memory measures, perhaps for a laboratory section or a research project, are provided in the Appendix.

COMPONENTS OF MEMORY RESEARCH

We approach memory from a scientific perspective to gain an objective understanding and minimize personal biases. As such, the ideas about memory discussed here reflect the work of scientists. To help you better understand how these people do their job, we first discuss what an experiment is and the different types of variables a researcher measures and controls.

What Is an Experiment?

Most of our knowledge of memory comes from experiments. So, what *is* an experiment? An *experiment* is a controlled situation in which a researcher manipulates variables of interest, measuring the effect of this manipulation, while keeping the irrelevant variables as consistent as possible. Furthermore, participants are randomly assigned to different conditions to reduce any unwanted systematicity. The variables being manipulated are the *independent variables*, such as how much a person has to remember, how long he or she has to remember it, and so forth. The active manipulation of these variables gives the researcher a great deal of control. The variables being measured are the *dependent variables*, such as how much is remembered, how accurate people are, how fast they remember, and so forth. Irrelevant aspects of the situation are known as *control variables.* This can include such things as the room lighting, the instructions, the apparatus used, and so forth.

For each experiment a researcher has a hypothesis about the outcome. A hypothesis is an educated guess or prediction about how the variation of the independent variables will be related to the outcome of the dependent variables. Often this is cast in some theoretical language about how memory is operating in the context of the experiment.

Other Types of Studies

The experiment is not the only way to study memory when experimental control is difficult or impossible. One alternative is a *correlation* study, where the performance of a dependent measure is assessed as a function of some preexisting variable. For example, one can look at memory as a function of age. Age cannot be experimentally controlled, but it is information that can be used to study memory. Alternatively, a researcher may do a quasi-experiment in which preexisting conditions are combined with the controlled assignment of the independent variables—for example, if one class of students memorized a set of 100 words and another class memorized a set of 100 pictures. Here, the assignment of students to conditions is not random but is based on the classes they are already in.

Finally, in some situations, it is not possible to study large numbers of people. Instead, the researcher can do a case study. When we look at the effects of brain damage, we can assess memory in specific individuals because they are the only ones available with a specific type of deficit.

Synopsis

There are various ways to study memory. The most common are experiments in which a researcher has control over the variables and can better assess what is affecting the observed outcome. The independent variables are manipulated, and the dependent variables are measured to see whether they conform to a hypothesis. In addition, it is also possible to use other methods, such as correlational, quasi-experimental, and case studies.

ASPECTS OF LEARNING

To test memory, some information first needs to be learned. How this happens is important. Was it something that was consciously learned, or was it something that was just picked up along the way? What kind of information was it, pictures or words?

Intentional versus Incidental Learning

Methods. An important factor is whether people explicitly *try* to learn. Explicit memorization is called **intentional learning.** The alternative is that a person just happens to learn something during the course of other activities. This is called **incidental learning.** An experimenter can explicitly alert a person that the information they are given is something that will be tested for later. These intentional learning instructions are direct, and they lead people to treat information more elaboratively. This elaborative processing can affect memory. Alternatively, if an experimenter gives incidental memory instructions, they have the person pay attention to and think about the information but not expend any extra effort memorizing it. In such cases, a cover task is given to orient people to the information. These cover tasks vary, and they can include things such as pleasantness ratings, sensibility ratings, or sorting information into categories.

Principles. In general, memory is better with intentional than incidental learning (see Block, 2009, for a review). This section outlines four principles that demonstrate the importance of the type of learning: levels of processing, mental imagery, the generation effect, and the automaticity of encoding.

Levels of Processing. An example of the influence of effort exerted during memorization is the **levels of processing** effect (Craik & Lockhart, 1972). This refers to the degree to which people elaborate on information during study. When people try to learn, they may simply repeat the information over and over. This is called **rote rehearsal.** In general, recall does not improve much with rote rehearsal, and recognition is only slightly improved (Glenberg, Smith, & Green, 1977). An example of the poor effectiveness of rote rehearsal is the results of a study by Nickerson and Adams (1979). Students at Brown University were shown individual drawings of pennies like those in Figure 3.1 and had to indicate whether it was correct. See if you can remember which one is correct. Students in this study were able to identify the correct drawing only 50 percent of the time. The penny with the highest rate of acceptance was incorrect version I (which 67 percent said was correct). Thus, repeated exposure does not improve memory.

In contrast, the more people think about the meaning of information, the more likely they are to use knowledge they already have, making inferences and elaborate on the to-be-learned information. This connecting of knowledge is called **elaborative rehearsal.**

Information that receives little elaboration is processed less. For example, suppose a task is to think about a set of words and only say whether the word is printed in upper-or lowercase

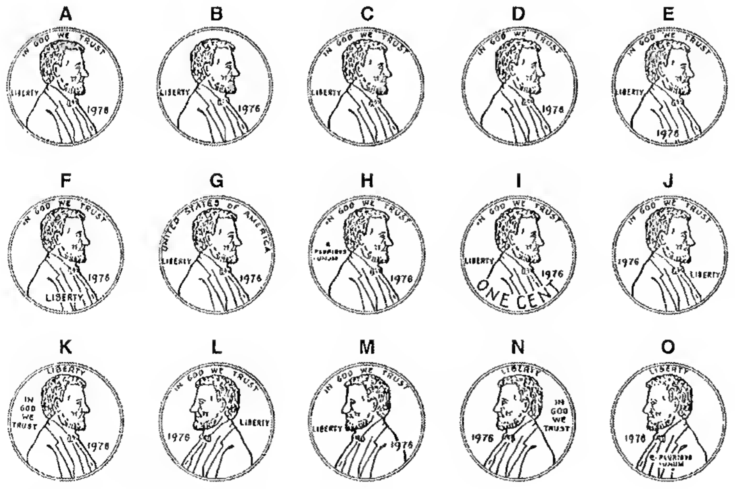

FIGURE 3.1 **Which Penny Is Correct?**

letters. This is shallow processing because it requires little attention to meaning and prior knowledge. However, if the task is to determine whether the word makes sense in a sentence, this is deeper processing. The levels of processing effect can occur for both incidental and intentional encoding (Hyde & Jenkins, 1973), although it is more likely to be observed during intentional learning.

Imagery. One way to elaborate on information and improve memory is by creating a mental image of what is being learned (e.g., Schnorr & Atkinson, 1969), as shown in Figure 3.2. Memories were better when you made a concerted effort to form mental images than when you simply rehearsed the information. Mental images do not appear spontaneously.

The benefit to memory of mental images led to the development of **Dual Code Theory** (Pavio, 1969), which suggests that people store information in memory in at least two forms: a verbal/linguistic code and a mental image code. These two codes can be associated to each other if they refer to the same thing. Memory improves because with mental imagery, there are multiple memory retrieval pathways to the same information and more memory traces containing the desired information. This makes successful remembering more likely.

Generation. According to levels of processing, the more information is elaborated on, the better it is remembered. This is shown by the **generation effect:** Information that a person generates is remembered better than information that is simply read or heard (Slamecka & Graf, 1978; for a meta-analysis, see Bertsch, Pesta, Wiscott, & McDaniel, 2007). For example, suppose people are presented with a series of word stems, such as TAB_____, and asked to complete the word. This is a generation task because the person

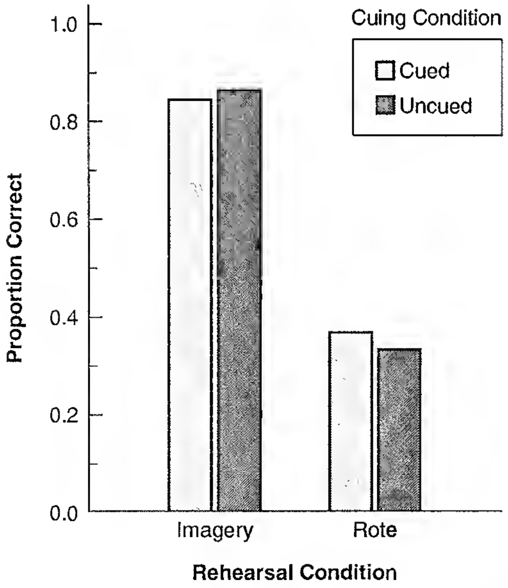

FIGURE 3.2 **Impact of Mental Imagery on Memory**

is generating the rest of the information. Alternatively, if people are simply asked to read a series of complete words, this is not a generation task because nothing is being created. The generation effect extends to a wide variety of information, including memory for the context in which something was learned (Marsh, Edelman, & Bower, 2001).

A generation effect is also observed when people solve a puzzle or problem. This is called the **"aha" effect** (Auble, Franks, & Soraci, 1979). For example, a person may have trouble initially understanding a sentence like "The man's back ached because the ends were too large." At some point, there is an awareness that this sentence is about using barbells and the person has an "aha" experience. Because the person generated his or her own solution, memory is better. Similarly, if people complete a connect-the-dots puzzle, the picture is remembered better than if it was seen already assembled (Wills, Soraci, Chechile, & Taylor, 2000).

In addition to generating words and ideas, memory is better when people actually perform a task compared to watching someone else do it or reading about it. This is the **enactment effect** (Engelkamp & Zimmer, 1989). Like the generation and aha effects, this is a form of elaborative rehearsal (Senkfor, Van Petten, & Kutas, 2008). This seems to take advantage of embodied aspects of cognition. For example, people remember words better if they are signed (as with American Sign Language) than if they are printed (von Essen & Nilsson, 2003; Zimmer & Engelkamp, 2003). However, this memory benefit only occurs when a person enacts only some of the items, not all of them (Dodd & Shumborski, 2009). People mentally organize and structure information differently when they perform an action (Koriat & Pearlman-Avnion, 2003). This provides a better means of retrieving the information. It has also been suggested that the enactment emphasizes the processing of individual items, rather than the relations among the items in a series (Steffens, 2007).

Automaticity. It should be noted that under some conditions the type of learning does not matter much. Memory can be similar with incidental and intentional encoding, depending on how people think about the information at the time (Postman & Adams, 1956; Salzman, 1953, 1956) and may not be present on certain memory tests, such as recognition (Eagle & Leiter, 1964; Postman, Adams, & Philips, 1955). In some cases there is an **automaticity of encoding** (Hasher & Zacks, 1979; 1984) in which information is stored in memory with little effort. Information that is automatically encoded does not benefit from further efforts at learning. Some types of information that may be more automatically encoded are knowledge of event frequency, time, and location. For example, think of how many times in the past month you've eaten out. The answer comes to mind relatively easily, and it is unlikely that you deliberately learned this as it was occurring. If you think about the knowledge that you have, some of it was very easy to learn, whereas some of it was learned only with a great deal of effort.

Stimulus Characteristics

During learning, it is also possible to manipulate the nature of the information itself. As already mentioned, some things are easy to learn and remember, whereas others require more effort and are more likely to be forgotten.

Methods. When studying memory, it is important to take into consideration what research participants think about the experiment. An adequate *task analysis* must be done. If not, it is possible that the researcher and the participant may interpret the task in different ways. What an experimenter thinks the participant is memorizing is the **nominal stimulus.** The stimulus the participant identifies and thinks about is the **functional stimulus.** Usually, these are the same things, but in some cases, they are very different. For example, a researcher might give people a list of nonsense syllables, one of them "DAX." In the experimenter's mind, this is just a meaningless series of letters. However, if the participant is an avid *Star Trek* fan, he would recognize this as the name of a character in the series.

Principles.

Savings. Stimuli affect memory in a number of ways. One of these, discovered by Ebbinghaus, is the principle of **savings.** After information has been learned and forgotten, a person requires less effort to learn it a second time. This is important for two reasons. First, this illustrates that although we may not be conscious of knowledge from our past, it may still affect our ability to learn and remember. Second, information we already know something about, even if we're not conscious of it, is easier to remember than something we encounter for the first time. In general, the more information taps into prior knowledge, the easier it is to remember. Thus, the meaning of a stimulus varies from person to person depending on the individual's experiences with and knowledge of it.

Pictures and Concreteness. In general, pictures are remembered better than words (Shepard, 1967; Snodgrass, Volvovitz, & Walfish, 1972; Standing, 1973). This is the **picture superiority effect**. It occurs because we are better attuned to perceptual than linguistic information. Also, a picture is more likely to be unique and contain a higher degree of detail. However, how easily pictures are remembered can vary depending on how meaningful they are. For example, it is easier to remember pictures of faces than pictures of snowflakes or inkblots (Goldstein & Chance, 1970). The picture superiority effect can be magnified with dynamic images (e.g., video) over static images (Buratto, Matthews, & Lamberts, 2009; Matthews, Benjamin, & Osborne, 2007).

Pictures and words are treated differently, even at a neurological level. For example, the right part of the hippocampus is more active for pictures, whereas the left is more active for words (Papanicolaou, et al., 2002). Furthermore, fMRI scans show that during picture encoding there is bilateral activation of the fusiform area (BA 37), the lingual-middle occipital lobe (BA 18, 19), and the inferior temporal gyrus (BA 20) (Vaidya, Zhao, Desmond, & Gabrieli, 2002). Moreover, the fusiform area and inferior temporal gyrus, is also activated during memory retrieval of pictures, even if the memory probes are words. So, the picture superiority effect reflects an engagement of a broader range of brain regions.

It has also been found that concrete information—words like "car," "house," or "book"—are remembered better than abstract information—words like "truth," "betrayal," or "redemption." This is the **concreteness effect.** Concreteness may aid memory because it involves more perceptual qualities, consistent with dual code theory. This distinction between concrete and abstract information is supported neurologically. Concrete words involve more basal extrastriate activation (BA 19), suggesting more perceptual processing (although there is some involvement in abstract processing as well) (Martin-Loeches, Hinojosa, Fernandez-Frias, & Rubia, 2001). Finally, there is greater right hemisphere activation for concrete words, whereas abstract words tend to involve more left hemisphere processing (Holcomb, Kounios, Anderson, & West, 1999; Kounios & Holcomb, 1994; Nittono, Suehiro, & Hori, 2002; Swaab, Baynes, & Knight, 2002).

Emotion. Memory can also be influenced by emotions, with emotional memories often being better (e.g., Kensinger, 2009; Kleinsmith & Kaplan, 1963; Phelps, 2006) and more vivid (Kensinger & Corkin, 2003a). Less emotionally intense information tends to involve an influence of the frontal lobes (LaBar & Cabeza, 2006; Phelps, 2006). However, with more intense emotions, this superior memory involves an influence of the amygdala, which then affects memory functioning in the hippocampus and medial temporal lobes, perhaps because the amygdala helps direct attention and memory to more emotionally relevant aspects of the world (Easterbrook, 1959; Phelps, 2006), although this may come at a cost to less emotional details (see Mather, 2007 for a review). More emotional events may affect memory because of their more primitive-, visceral- and survival-based qualities.

In addition to emotional intensity, memory may be affected by the emotional valence. That is, whether something is emotionally positive (e.g., courage) or negative (e.g., ordeal). According to the **Pollyanna principle,** there is a tendency to better remember positive than negative information. For example, positive words are learned more quickly than negative words (Anisfeld & Lambert, 1966; Stagner, 1933). However, there are circumstances where negative information is remembered better (Ortony, Turner, & Antos, 1983), such as with flashbulb memories for surprising, and often negative, events (see Chapter 13). Also, negative words are learned more quickly than emotionally neutral words (like *wood,* for example) (Carter, 1936; Carter, Jones, & Shock, 1934). Finally, relative to neutral information, negative memories are more likely to benefit from the consolidating effects of sleep (Payne, Stickgold, Swanberg, & Kensinger, 2008).

Frequency. Another quality that can affect memory is **frequency.** Frequency is a bit odd in that memory is better for frequent information for recall tests (e.g., Taft, 1979), but better for rare information for recognition tests. Common things are easier to recall because there are more ways to get at them, making them more likely to be recalled. However, with recognition, less-frequent items have fewer competitor memories, so they are recognized more easily (see the following sections on recall and recognition).

Survival. Recent work has looked at the influence of evolutionary pressures on memory effectiveness (Nairne & Pandeirada, 2008b). People respond faster to words based on their subjective level of danger or usefulness (Wurm, 2006; Wurm & Seaman, 2008). Also, in some studies, people are given lists of words, and asked to rate each word on its survival value, such as locating food or avoiding predators. Focusing on the fitness-related value provides some of the best memory compared to other ways of boosting memory (Nairne, Thompson, & Pandeirada, 2007; see also Kang, McDermott, & Cohen, 2008; Nairne & Pandeirada, 2008a). Moreover, memory seems more attuned to grasslands survival than city survival (Weinstein, Bugg, & Roediger, 2008). Compared to other ways of boosting memory, including creating mental images, generating information, and intentional learning, as can be seen in Figure 3.3, recall memory is best when people learn the information by attending to its survival value (Nairne, Pandeirada, & Thompson, 2008).

Synopsis

How information is learned and the nature of that information can affect memory. Memory is usually better when people intentionally learn something than when they learn it incidentally, as reflected in the levels of processing framework, the influence of mental

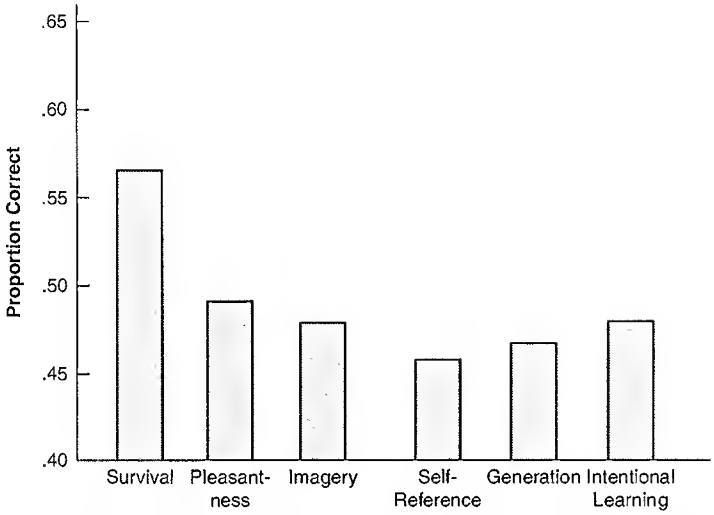

FIGURE 3.3 Influence of Survival Processing on Memory Compared to Other Standard Memory Improvement Methods

imagery, and the generation effect. However, some things are learned more automatically. Memory is also influenced by what is remembered. Memory is better for things that a person already knows and for pictures, concrete information, and emotional things. Recent work suggests that information related to survival is remembered best.

ASSESSING THE CONTENTS OF MEMORY

Questions about memory often center around issues of what information is in memory, what can be remembered later, and how easily it is remembered. There are a number of ways of getting at the contents of memory, and each has its advantages and disadvantages.

Recall

Methods. A straightforward way to test memory is the **recall** test. For recall, a person needs to report whatever he or she can retrieve from memory. There are many types of recall tests.

Free Recall. The most basic recall test is **free recall,** in which people report as much information as they can. This is similar to answering an essay question on an exam. Because there is very little additional information provided, free recall is a good way to find out what a person knows very well. Presumably, this is what is reported. Information that a person knows, but not very well, is less likely to be reported because the person is less likely to successfully retrieve it.

Free recall data can also be used to study errors of omission (what people don't remember) and errors of commission (information that is reported as memories, but was not, in fact, part of the event). These are called **intrusions,** and they can be important when studying false memories (see Chapter 12). Studying **recall order** can give insight into how memories are structured. This is discussed in more detail in the section on cluster analyses.

Forced Recall. One problem with free recall is that there might be information that people remember, perhaps faintly, but that they are unwilling to report in case they might be wrong. Also, sometimes people report memories more generally when they actually have more precise knowledge (Goldsmith, Koriat, & Weinberg-Eliezer, 2002). One way to encourage people to report these weaker memories is to give a **forced recall** test. Unlike a free recall, where a person can report as much or as little as desired, in a forced recall test a person is forced to report a certain amount of information. Typically, this is more information than what would have been reported under free recall. Using this approach, weaker knowledge in memory can be assessed as being present. Typically, this weaker knowledge is provided toward the end of forced recall. Forced recall can also be used to elicit intrusions. These errors can be informative about the processes people use to recover memories by illustrating how that process can break down. In other words, the mistakes that people make are not random, but they follow certain principles. Studying these errors can provide insight into how memory works.

Cued Recall. Memories are often associated with a context or setting. There are many things in the environment that can serve as context. To get a better idea about how context influences memory retrieval, a **cued recall** test can be used. During memorization, people learn a set of information. The experimenter designates some of this information as target information to be recalled. Associated with this are other sets of information that serve as retrieval cues. Thus, the experimenter is controlling the context that will be relevant later. The paired associate learning tasks discussed in Chapter 1 are a good example of this sort of cue and target knowledge learning.

During retrieval, the experimenter provides a set of cues, and the task is to report the information that goes with those cues. Thus, the experimenter controls the context and can observe how it influences memory. Retrieval is more constrained than under free recall conditions. During cued recall, people respond to either as many cues as they can or to all of the cues, much like a forced recall test. Again, both accuracy and errors can help to understand the contents of memory.

Retrieval Plans. During recall, people need to mentally organize the information to be able to retrieve it later. This includes both recalling information that has not yet been reported as well as avoiding reporting something that has already been recalled. To monitor memory retrieval, people often develop a strategy known as a **retrieval plan.** This is a set of retrieval cues used to guide a person through the information. As we will see in Chapter 7, if this retrieval plan is thwarted or disrupted by external influences, performance declines. This is true even when the cues are some of the elements that must be remembered, which, on the face of it, should help memory.

Principles.

Forgetting Curve. Perhaps the clearest finding to come out of research using recall is that the more time that has passed, the less likely a person will remember a given piece of information. Or, to put it simply, people forget more as time passes. The way forgetting proceeds was one of the first things discovered using recall tests. In Ebbinghaus's studies he was able to track his performance at various time intervals. What he observed is the **forgetting curve,** shown in Figure 3.4. A forgetting curve is a negatively accelerating function. That is, the rate of forgetting is most rapid initially after the information was learned. As time passes, although the cumulative amount of knowledge loss grows larger, the rate of this accumulation slows

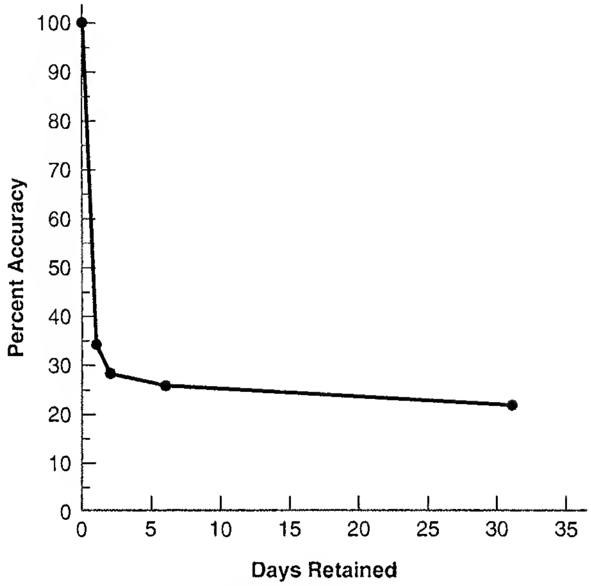

FIGURE 3.4 A Forgetting Curve

down accordingly. This forgetting function is captured by **Jost's Law** (1897; as cited in Wixted, 2004b) which states that for memories of a similar strength, the older memories will decay more slowly relative to the newer memories. Careful research has shown that the forgetting curve follows a power function (e.g., Anderson & Schooler, 1991; Rubin, 1982). However, it is unclear whether this is because of some fundamental exponential neurological process or because of some artifact of average across many trials (Anderson, 2001).

Forgetting curves are one of the most reliable observations in human memory and occur with all kinds of information. The rate of forgetting is similar across different levels of learning (Meeter, Murre, & Janssen, 2005). In other words, although people learn information to different degrees, they all forget the information at the same rate. So, the people who knew more initially almost always know more later on as well. Moreover, although we bring up the forgetting curve here in this section on recall tasks, forgetting curves are readily observed with other tasks as well, such as recognition.

Overlearning. The consistency of the forgetting curve is reassuring in its stability. Yet, at the same time, it is deeply disturbing in its suggestion that everything we've ever learned or known is fated to be forgotten at some point. While there is a truth in the forgetting curve, it is not always the case that forgetting inevitably occurs. Another principle that Ebbinghaus discovered using recall was overlearning. **Overlearning** occurs when a person continues to study information after it is already possible to recall it without errors. This continued practice causes the forgetting curve to lessen and possibly disappear altogether. In such cases, the information becomes chronically available and is greatly resistant to forgetting. Thus, many of the fundamentals you remember from your schooling, such as the "A, B, C" song, have been greatly overlearned, and you are unlikely to forget that knowledge. This is one reason why education emphasizes repetition and practice.

Reminiscence and Hypermnesia. Not only do we forget things all the time, but we can also remember things that were once forgotten. This principle of remembering previously forgotten information is called **reminiscence** (Ballard, 1913). Generally, reminiscence is observed with a recall task, particularly free recall. Although reminiscence occurs, so does forgetting. Thus, if the times that a person tries to remember are spread out, even though reminiscence is occurring, the person may be remembering less and less overall. However, if a person tries to recall information several times in a row, the rate of reminiscence may be greater than the rate of forgetting. Under such circumstances the person is cumulatively remembering more and more each time (Erdelyi & Becker, 1974; Wheeler & Roediger, 1992). This is called **hypermnesia** (the opposite of amnesia). Hypermnesia has been documented under a number of circumstances, but it is difficult to observe. It is more likely to be seen with pictures (Payne, 1987) and with shorter intervals between recall tests (Wheeler & Roediger, 1992). It is also more evident in free and cued recall situations than with recognition (Otani & Hodge, 1991). This may occur because the pieces of information in a set that are recalled earlier can serve as cues to assist the retrieval of the information that was previously forgotten.

It should also be noted that while shorter delays (e.g., a few minutes) are more likely to produce hypermnesia than longer ones (e.g., a few hours), at very short delays (e.g., a few seconds), whatever causes hypermnesia may not have time to operate. For example, using lists of words, hypermnesia does not occur if the delay is less than five seconds per word, but it does occur if more than five seconds per word is given (Payne, 1987).

The existence and operation of reminiscence and hypermnesia have practical significance. When it seems that you have completely forgotten a piece of information, putting it out of your mind for a period of time may help you remember it later. Of course, as with any type of memory, the more elaborately you think about the information during learning, such as forming mental images, the more successful later attempts to remember will be, even for reminiscence and hypermnesia.

Recognition

During recall, people need to generate the information, at least in part. However, in some cases, people need only to identify something already in their environment as being familiar or old, and thus recognized, or as being unfamiliar or new, and thus unrecognized. **Recognition** is a process in which the contents of the environment are compared with the contents of memory. If there is a match, then recognition occurs; otherwise it does not.

Methods.

Old-New Recognition. The simplest form of recognition testing is **old-new recognition.** In this method a person is given an item and is asked to indicate whether it is old or new. Memory is assessed based on the pattern of responses. This method simplifies the retrieval situation, making it easier to track and analyze. A great deal of information can be derived from such simple tasks. Sophisticated approaches can lead to penetrating insights into the contents and process of memory. Neurocognitive EEG recordings show that when items are recognized, there is an initial increase in synchronization of theta activity around the parietal lobe, followed by decreased synchronization in the upper and lower alpha bands around the temporal lobe (e.g., Burgess & Gruzelier, 2000).

Correction for Guessing. For simple old-new responses, some accurately reflect a person's memory, but others involve a degree of uncertainty, and are guesses. Suppose a person identified 50 items correctly on a memory test. If that person had no incorrect answers, then it would seem that his memory was very accurate. However, if that person got 50 wrong and 50 correct, then it would appear he was guessing. What is needed is some way to correct for guessing, to provide a more accurate estimate of memory.

A simple way to correct for guessing is to subtract the number of incorrect responses from the number of correct responses. And in some cases this is what is done. However, this is a rather crude adjustment, and it can miss more subtle aspects of performance. Guessing can be affected by two pieces of information. One is the degree to which old items can be distinguished from new ones in memory. This is called **discrimination.** Sometimes discrimination is relatively easy, such as identifying whether a person is a famous actor versus someone you've never heard of before.

The second piece of information is the degree to which a person is willing to accept what is remembered as new or old. This is called **bias.** Sometimes, people may adopt a strict criterion and have a "conservative" bias. In this situation, people accept only cases in which they are very sure that the information is old; so there are no false alarms. A **false alarm** is calling something old that is, in fact, new. A situation in which a person might be motivated to adopt a conservative bias would be in eyewitness identification. The eyewitness wants to be sure that the person he or she identifies is the criminal. Picking out the wrong person could lead to an innocent person being punished for a deed he or she did not commit and leaving the true guilty party at large, free to commit more crimes. In other cases, people may adopt a loose criterion and thus have a "liberal" bias. In this situation, people are more willing to accept a memory that has a more remote possibility of being old to avoid making any **miss** responses. A miss response is calling an item new that is in fact old. A situation in which a person might be motivated to adopt a liberal bias would be in looking for a lost set of keys. The searcher wants to be sure that all plausible locations are checked.

One method for estimating discrimination and bias is **signal detection theory** (Banks, 1970; Lockhart & Murdock, 1970). This approach has been adopted from psychophysicists, who, in turn, borrowed it from communications theory. By using this approach, one can derive a measure of discrimination, often called d', and of bias, often called β. (see Snodgrass & Corwin, 1988, for various measures of discrimination and bias.)

The basic idea is to assess the ability to detect the signal (an accurate memory) from the noise (inaccurate memories). The thinking in signal detection theory is illustrated in Figure 3.5. This approach assumes that there are two distributions: one for the old items and one for the new items along some dimension, such as familiarity. The farther apart these two distributions are, the easier it is to discriminate between them. Conversely, the more these two distributions overlap, the harder it is to discriminate between them. Keeping the distance between the two distributions constant, we can see how bias affects memory performance. The criterion a person uses to separate out what is identified as old and new is measured by β. If β is set very far to the right, the person has adopted a conservative criterion, and very few memories will be accepted as old. However, if β is set far to the left, the person has adopted a liberal criterion, and very few memories will be accepted as new.

Forced-Choice Recognition. Another form of recognition is when people are given several items and are asked to indicate which one is old. This is **forced choice recognition.** Typically, there are two, three, or four alternatives. Forced choice recognition allows a researcher to manipulate the incorrect items in terms of the degree to which they resemble the correct one. Such manipulations can provide insight into what sorts of knowledge

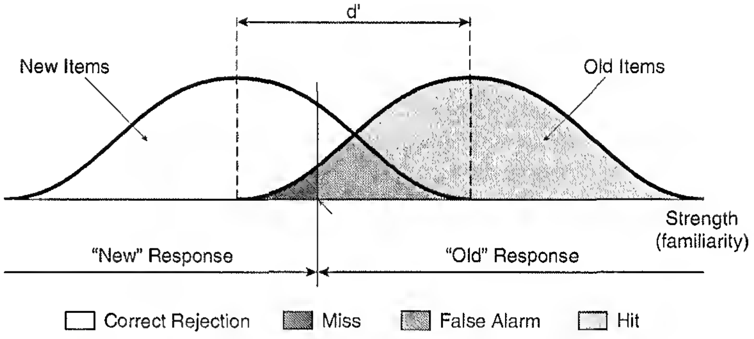

FIGURE 3.5 Illustration of the Underlying Logic for Signal Detection Theory

people are using when remembering something. The wrong items that are more often selected as "old" would more closely match the information in memory, thus lending some insight into the contents of memory.

Social Influences

Many of the studies discussed here have a person largely alone in the environment. However, in the real world, people are in social situations, interacting with others in complex ways. These other people can influence memory. For example, people remember events differently depending on who they are with (who they are telling their story to), which can then bias later memories for the event (Tversky & Marsh, 2000). Moreover, people who work with high-performing individuals will recall more later than people who work with low-performing individuals (Reysen, 2003), and people remember information better if they think it comes from another person as compared to a computer (Reysen & Adair, 2008). Even how well we remember someone's face depends on social influence. For example, people remember pictures of faces better when the person in the picture is looking at them versus when they are looking away (Mason, Hood, & Macrae, 2004). Thus, how well we remember is influenced by the people with whom we interact with. Now let us look at other social influences on memory.

Collaborative Inhibition. Is memory affected by whether people are remembering things alone or in a group? Studies have found that when people in groups try to recall something, they typically recall less than if they were separated, asked to recall information, and had their individual efforts pooled (Basden, Basden, Basden, Bryner, & Thomas, 1997; Weldon & Bellinger, 1997). This decline in memory when working in a group is **collaborative inhibition.**

Collaborative inhibition may seem to reflect some sort of social loafing. However, what is actually going on is that a person is encountering different ways that other people have structured the information. Each person's recalls are based on his or her own retrieval plan. When confronted with an organization that is inconsistent with one's own retrieval plan, the ability to recall becomes disrupted, and performance declines (Finlay, Hitch, & Meudell, 2000; Weldon, Blair, & Huebsch, 2000). This is related to the part-set cuing phenomenon (see Chapter 7). It should be noted that although people recall more as individuals than in groups, recalling in groups does increase the accuracy of the recalled information (Vollrath, Sheppard, Hinsz, & Davis, 1989).

Collaborative Facilitation. Although memory is worse on recall tests in groups than alone, the opposite is true for recognition (Hinsz, 1990; Rajaram & Pereira-Pararin, 2007; Vollrath, Sheppard, Hinsz, & Davis, 1989). This is **collaborative facilitation.** In recall, the retrieval plan plays an important role in performance. In contrast, in recognition there is no retrieval plan. Memory only requires that something seem familiar, and anything more is a bonus. When people do recognition in groups, they can pool their resources to arrive at some consensus about what happened, although this is more effective at accepting old items than rejecting new items (Clark, Abbe, & Larson, 2006; Clark, Hori, Putnam, & Martin, 2000). Issues of social influence on memory are discussed more prominently in Chapter 12 (Memory and Reality) and Chapter 13 (Memory and the Law).

Other People's Memories. In addition to the influence of other people on our own memories, we may also be called upon to evaluate the quality of other people's memories. While we can do this to some degree, there are some biases that can creep up. One is the *consensus bias* (Ross, Greene, & House, 1977), which is the idea that we often assume that other people know what we know. So, if we have some idea or information in memory, we implicitly expect other people to know this as well. Another bias is that people expect others to do better when the pressure is on to remember something. While motivation to remember can help when a person is first encoding something, it does not help much, if at all, during retrieval. However, other people expect a person to remember more when they are motivated at retrieval, even though this doesn't really help (Kassam, Gilbert, Swencionis, & Wilson, 2009). Imagine a high-profile court case in which a person is strongly motivated to remember something accurately. If he was trying to remember at the time the event occurred, then it is reasonable that memory will be better. However, if he was only motivated to try to remember at retrieval of something that did not seem particularly important at the time, then memory will be relatively poor in spite of the motivation. Despite this, other people will expect the person's memory to be better because of this lack of insight we have into how other people's memories work.

Synopsis

Two of the most common ways to test memory are recall and recognition. Recall involves producing information. Often people need a retrieval plan to help organize their recalls. Recall tests have helped illustrate such basic principles as the forgetting curve, overlearning, reminiscence, and hypermnesia. Recognition involves assessing whether something has been encountered before, such as with old-new recognition tests, although some correction for guessing may be needed. In more complex situations, people may be given forced-choice recognition tests in which they need to select one option from a set of alternatives. Finally, memory retrieval can be influenced by social circumstances. Sometimes other people can hinder memory, as with collaborative inhibition, whereas other times other people can augment memory, as with collaborative facilitation.

ASSESSING MEMORY STRUCTURE AND PROCESS

We have looked at methods that assess the contents of memory. In this section we cover ways of looking at memory structure and the processes that are used in retrieval. The structure of memories refers to both the organization of multiple pieces of information within a single memory trace or across multiple memory traces. The processes of memory refer to the mental activities that a person engages in when trying to retrieve a piece of knowledge. Basically, *how* do we remember?

Mental Chronometry

An important and frequently used source of information in memory research is the speed of responding. In many cases this **response time** is recorded on the order of milliseconds or seconds. The idea is that faster response times reflect simpler memory processes and/or more familiar memories, whereas slower response times reflect more complex memory processes and/or more unfamiliar memories.

Methods. Response time is measured from the onset of some stimulus. For example, when asked to identify whether a series of faces has been seen before, the time will be recorded from the moment the picture was shown to the time the person responds. The time recorded for any given memory is not very informative by itself. That time must be placed in some context of other times to understand whether it is fast or slow. While there are many variations on this idea, the use of response times can be classified into two broad categories.

The first description of mental chronometry was Donders's **subtractive factors logic.** This is outlined in Figure 3.6. The idea is to have at least two conditions that are identical except for the inclusion of one processing step. For example, both conditions include the same encoding (factor A) and response (factor B) processes. However, the condition of interest involves an extra step (factor X). After collecting the times, the time for the simpler process (A + B) is subtracted from the time for the more complex one (A + X + B). What is left over should be the time for the critical process. For example, in a simple condition one could have a person indicate whether a picture of a face is old or new. In a more complex condition the person would indicate whether a picture of a face is old or new and whether the person is living or dead. Based on subtractive factors logic, the difference between these two conditions would reflect the time it takes to remember a person's current health status.

While subtractive factors logic is appealing, it has a number of problems. For one, it is unclear whether the process of interest is being added in a way that does not disrupt or change others and that occurs at a time when these other processes are not taking place. Another approach to mental chronometry is **additive factors logic,** developed by Sternberg (and discussed in more detail in Chapter 4). This approach is outlined in Figure 3.7. Rather

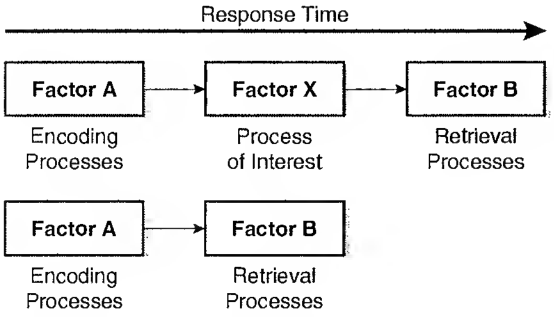

FIGURE 3.6 **Donders's Subtractive Factors Logic for Response Times**

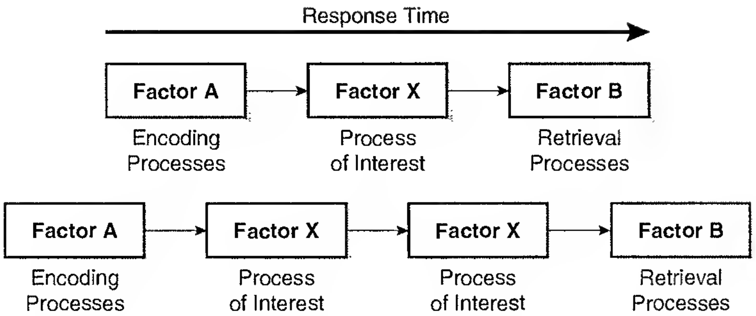

FIGURE 3.7 Sternberg's Additive Factors Logic for Response Times

than having two conditions that differ by the presence or absence of a mental stage, in additive factors logic the critical stage of interest (factor X) is always present. What varies is its degree of involvement—that is, how much of that process is added relative to a comparison condition. For example, it may be a stage that a person needs to go through many times or that it involves various numbers of memory traces. By looking at the differences among conditions, one can provide an estimate of the influence of each increment of complexity. This approach is more likely to preserve a greater array of mental processes across conditions, making the comparison more reliable and meaningful.

Principles. The analysis of response times has yielded a wealth of information about memory. One of the most prominent of these is priming. **Priming** is a speed up in response time to items that immediately follow related items. For example, when making lexical decision judgments (that is, deciding whether a string of letters is a word or not), people are faster to say that the string "doctor" is a word if it immediately follows "nurse" than if it follows "bread" (e.g., Meyer & Schvanevelt, 1971). The idea is that "nurse" activates or primes knowledge of nurses in long-term memory. The concept "doctor" is very related to "nurse," and so has been primed. So, information about doctors is retrieved faster than it would have been had the person just been thinking about something unrelated (like bread). This sort of unconscious, implicit influence on memory, while typically studied across brief periods of time (anywhere from a few milliseconds to several minutes), can last for years. One study reported significant priming 17 years after people initially had only 1–3 second exposures to pictures (Mitchell, 2006).

Cluster Analysis

Some methods of assessing memory are aimed at directly indicating how information is organized. Knowing this can provide insight into how things such as remindings occur and why our thoughts drift in some ways but not in others. There are a number of ways to approach this question. Looking at the data from priming studies is one way. Regardless of the method, what is going on in such studies is an attempt to look at clusters of memories. In fact, there is a special domain of statistics known as cluster analysis where the goal is to detect groups or clusters of information in a set of data.

Methods. There are a number of methods that can be used to look at clusters of information in memory. Here we focus on two relatively simple measures to give you a feel for how this approach works.

Inter-Item Delays. A time-based procedure for assessing memory organization with recall is if you keep track of the amount of time between each recalled item. What you'll find is that there is not a uniform pattern. Instead, people report a burst of a few items, then a pause, then a burst of a few more, and a pause, and so on (e.g., Patterson, Meltzer, & Mandler, 1971; Pollio, Richards, & Lucas, 1969). By using these **inter-item delays,** one can make inferences about memory structure. Memories that are structured together are likely to be recalled together during one of the bursts. However, information that is stored apart is more likely to be separated by a longer pause or delay.

ARC Scores. There are also methods of obtaining memory clusters by looking at the content of recall, specifically the order in which information was reported. Pieces of information that are stored together in memory are likely to be recalled together. In many cases you can make a reasonable guess about how a set of information could optimally be organized. For example, a set of words can be organized into categories. It then becomes possible to test whether people have adopted that organization. This can be done by calculating Adjusted Ratio of Clustering (ARC) scores (Roenker, Thompson, & Brown, 1971). ARC scores index the degree to which a recall sequence conforms to predetermined categories, taking into account how much organization would be expected by chance. The formula for calculating ARC scores is given in the Appendix.

There are many sorts of analyses that address the organization of information. For example, the ARC' score measures the degree to which a recall conforms to a predetermined sequential order (Pellegrino, 1971). (The method for calculating ARC' scores is also provided in the Appendix).

Subjective Organization. There are ways to get at subjective organization—that is, the organization imposed by the person himself or herself rather than the experimenter. This is useful when there is no clear a priori organization. One of these is a measure that produces an ordered cluster tree (e.g., Reitman & Rueter, 1980). Basically, people are asked to recall a complete set of information a number of times. What this measure then does is look for consistencies in these repeated recalls, both in terms of the clusters that might be present as well as any stable sequential orders that might be produced.

Another way to assess how people subjectively organize information is to have them indicate where breaks should occur when they are viewing continuous events. For example, people might watch a film in which they are asked to press a button every time they think there has been an important shift in the situation. The locations that people select as break points are thought to correspond to separation of different types of information in memory (Magliano, Miller, & Zwaan, 2001; Newtson, 1976; Zacks, Speer, & Reynolds, 2009).

Principles. Clustering methods have shown that memories are highly structured. This structure may take the form of a hierarchy. The more structure a person can impose on information, the better his or her recall will be (Mandler, 1967). When people are given a set of information, they often adopt that structure, which is seen in how they remember it. For example, in a study by Bousfield (1953), people were given a list of 60 words to memorize. These words were from four categories (i.e., animals, people's names, vegetables, and professions), but they were presented in a random order. When people later recalled those words, there was a strong tendency to recall them in clusters based on the four categories. Moreover, as time passes and people have more experience with a set of information, their memories become more organized (e.g., Bousfield & Bousfield, 1966). In fact, experts in a domain have highly organized knowledge bases.

Finally, even when given what appears to be a random set of information, people impose some subjective organization upon it (Tulving, 1962). This subjective organization takes into account the idiosyncratic interpretations people place on a set of items to create a structure that will help them remember. While space may abhor a vacuum, the human brain abhors randomness. It is always searching for regularities and structure.

Synopsis

There are a number of ways to look at the structure and function of memory. Mental chronometry allows us to look at how long it takes to remember something to help draw conclusions about memory structure, organization, and complexity. Priming is a classic example of the how mental chronometry can yield insights into memory. Cluster analyses assess more directly how knowledge is structured in memory.

CONSCIOUS EXPERIENCE OF MEMORY

Metamemory Measures

Another important characteristic is the phenomenological experience of memory. The awareness of one's own memory and memory processes is known as **metamemory** and is highlighted in Chapter 14. A brief coverage of metamemory issues is presented here to illustrate how to study the experience and awareness of memory.

Methods. Metamemory studies require people to report their own memory processes. This method of introspection has a long and checkered past dating back to the early days of experimental psychology, and many people are still cautious about using such **verbal reports** (e.g., Nisbett & Wilson, 1977) because many of our thought processes lie outside of conscious awareness. However, despite this, there are still cases where verbal reports can provide insights about cognition (e.g., Ericsson & Simon, 1980), especially if one is concerned with conscious mental states and their consequences.

There are a number of metamemory methods. A common one is remember vs. know judgments (Gardiner, 1988). With this approach, people are asked to recall or recognize a set of information. For those things that are recalled or identified as old, people then rate whether the information is something they consciously remember learning or something they know they encountered before but have no conscious memory of learning it. For example, if you can recollect where and when you learned of your acceptance into college, then you would say that you remember it. In contrast, if you have no conscious memory of this event, but you know it must have occurred, then you would say that you only know it.

Principles. A number of insights have been gained by looking at what people attribute to their own memory processes. People can be led astray and become biased when assessing their own memories. This is clearly illustrated by the hindsight bias (e.g., Fischhoff, 1975). The hindsight bias is a tendency to distort memories so they conform to one's goals or circumstances. For example, people might be asked to make predictions about how likely an event is to occur. Then some time afterward one group (the experimental group) is presented with information about the actual outcome. Another group (the control group) is not given this information. If everyone then reports his or her original estimates, those in the experimental group are more likely to "misremember" their original estimates as being much closer to the actual outcome. We'll discuss this more in Chapter 14.

Implicit Memory

Again, implicit memory refers to memories and memory processes that are unconscious. It is rare that memory uses only implicit or explicit processes. Performance almost always reflects a mixture of these two processes. However, there are methods that allow for the effects and influences of each of these to be separated.

Methods. Measures that are aimed more at implicit memory use tasks in which people are not aware that memory is being tested or when there is little to no conscious control over the process. In general, it is very difficult, if not impossible, to have a memory task that purely taps either implicit or explicit memory. As such, memory *tasks* are referred to as either **direct memory tasks**, which directly ask a person for a memory report (such as recall and recognition), or **indirect memory tasks**, which assess memory by focusing a person's attention on another aspect of the task. In general, direct memory tasks are thought to involve more explicit memory and indirect memory tasks are thought to involve more implicit memory. Indirect memory methods often either tap preexisting knowledge or present people with a set of information and then test memory some time afterward. In the latter case, the memory tests are given under the guise of being unrelated to what had been done previously so people are not motivated to consciously remember. Indirect memory measures include such things as word fragment completion, perceptual identification, and priming.

One method for separating out implicit and explicit memory processes is the **process dissociation procedure**. Because there are no "process pure" tasks, with almost any task including both conscious and unconscious components, this procedure can help estimate their relative influence (e.g., Jacoby, 1991). For example, suppose a person has read a list of words and then takes a word fragment completion test. This procedure works by having people recall information under two conditions. In the *inclusion* condition, the person completes a series of word fragments with whatever words he or she can think of, even if they were words from the prior list. In the *exclusion* condition, a person uses any word he or she can think of as long as they are *not* words that were on the previous list. Using performance in these two conditions, it is possible to arrive at estimates of explicit and implicit memories. The procedures for calculating these components using the process dissociation procedure are given in the Appendix.

Synopsis

It is important to know what it feels like to remember something. Awareness of one's own memory is known as metamemory. Studies of metamemory reveal our insights into our own memories as well as how these insights can be wrong. It is also important to realize that many memory processes occur outside of awareness in what is known as implicit memory.

SUMMARY

This chapter covered a number of methods for assessing memory and some basic principles that they illustrate. Each method has its strengths and limitations. To gain the most accurate picture of memory, it is important to use multiple methods. The more methods that point to the same answer, the more reliable that answer will be. However, if different methods lead to different answers, then something is wrong. For example, suppose there are two conditions. In one, people are more accurate. However, if they also are much slower, then this is known as a speed-accuracy tradeoff. Because people are making fewer errors and slowing down, it may just mean that they are being more careful, not that these data reflect anything about memory per se. More generally, multiple sources of data can be used in combination to provide a more complete picture of how memory operates (Meyer, Irwin, Osman, & Kounios, 1988). Because of our lack of direct access to memory, we need a variety of methods. Converging operations allow us the greatest level of certainty about one of the more elusive topics in science.

STUDY QUESTIONS

1. What is an experiment? What are the primary components of an experiment? Why is this a preferred way to study memory?
2. What are some ways to learn information so it can be better remembered later? Is this true of all kinds of information?
3. What kinds of information are easier to remember? What kinds are more difficult?
4. What are the various sorts of recall tests, and what can they reveal about memory?
5. What are the various sorts of recognition tests, and what can they reveal about memory?
6. What are some of the ways to correct for guessing on memory tests?
7. What are some of the ways in which social situations influence how well memory works?
8. How can mental chronometry be used to assess characteristics of memory? Give an example of some phenomenon of memory that is clearly shown using mental chronometry.
9. How are cluster analyses used to study memory?
10. What is metamemory, and what does it tell us about how people use their memories?
11. What is implicit memory, and, generally, why is it important to memory functioning?

KEY TERMS

additive factors logic, "aha" effect, automaticity of encoding, bias, collaborative facilitation, collaborative inhibition, concreteness effect, cued recall, direct memory tasks, discrimination, Dual Code Theory, elaborative rehearsal, enactment effect, false alarm, forced recall, forced choice recognition, forgetting curve, free recall, frequency, functional stimulus, generation effect, hypermnesia, incidental learning, indirect memory tasks, intentional learning, inter-item delays, intrusions, Jost's Law, levels of processing, nominal stimulus, metamemory, miss, old-new recognition, overlearning, picture superiority effect, Pollyanna principle, priming, process dissociation procedure, recall, recall order, recognition, reminiscence, response time, retrieval plan, rote rehearsal, savings, signal detection theory, subtractive factors logic, verbal reports

TRY IT OUT

In this chapter there are a number of basic ideas for research projects on memory. For many of these, you can create a list of 20 or so words and use these as your stimuli. When you generate these lists, try to keep the words similar in some way, such as all being from the same class of words (e.g., nouns or verbs), being similar in length (e.g., five to six letters long with two syllables), and so on. When you present the information to people, try to keep the presentation time constant in the different conditions. Typically, for word lists, people might see each word for one second each (you could write each word on an index card). To encourage some forgetting, have people do a distractor task, such as solve three-digit math problems (294 + 603 = ?) for two minutes. Ideally you should have at least 12 participants for each of these tasks, with at least 12 people in each group if you decide to vary things in your own experiment between groups. Now, with these basic ground rules, here are some things you could do:

- Test the difference between **incidental** and **intentional** learning by having one group of people (incidental) rate each word for pleasantness, and another group of people (intentional) study each word knowing that they will get a memory test later. After the distractor period, have people write down as many words as they can remember. If all goes well, people in the incidental learning group will remember less than people in the intentional learning group.
- Test the effectiveness of **imagery** by giving the list of words to two groups of people. Have one group (control) simply try to learn the words as effectively as possible. Have the other group (imagery) try to form mental images as they study each word. After the distractor period, have people write down as many words as they can remember. If all goes well, people in the imagery condition will remember more words than people in the control condition.
- To show the effectiveness of **concreteness**, have two groups of people. Keeping everything else the same, such as the length of the words, give one group a list of nouns that refer to concrete objects (e.g., truck), and give the other group a list of nouns that refer to abstract concepts (e.g., trust). After the distractor period, have people write down as many words as they can remember. If all goes well, people in the concrete word group will remember more words than people in the abstract word group.
- To demonstrate a **forgetting curve**, give your people four lists of words. Have them recall one list immediately, a second list after one hour, the third list after one day, and the fourth list after one week. If all goes well you should find that memory for the word lists will decline in a way that shows the greatest rate of forgetting soon after the list is read, and a slower rate of forgetting at longer periods of time.